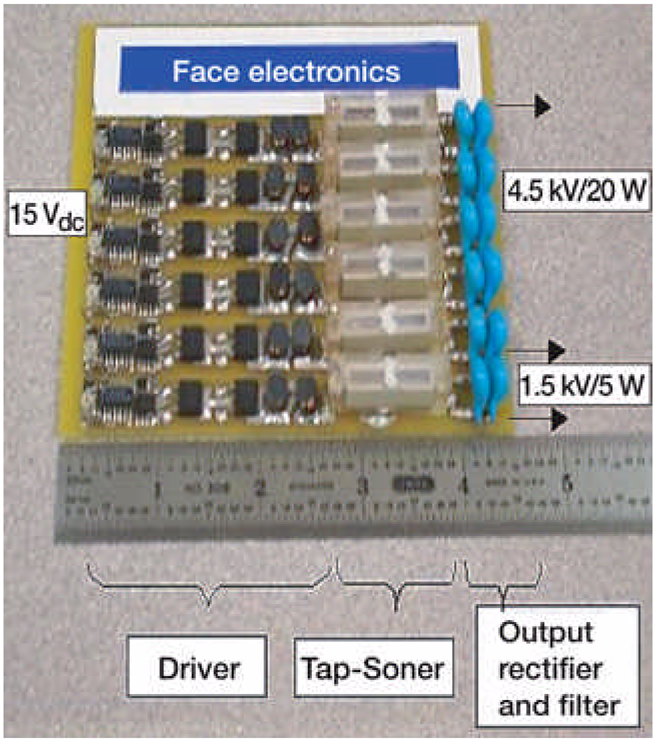
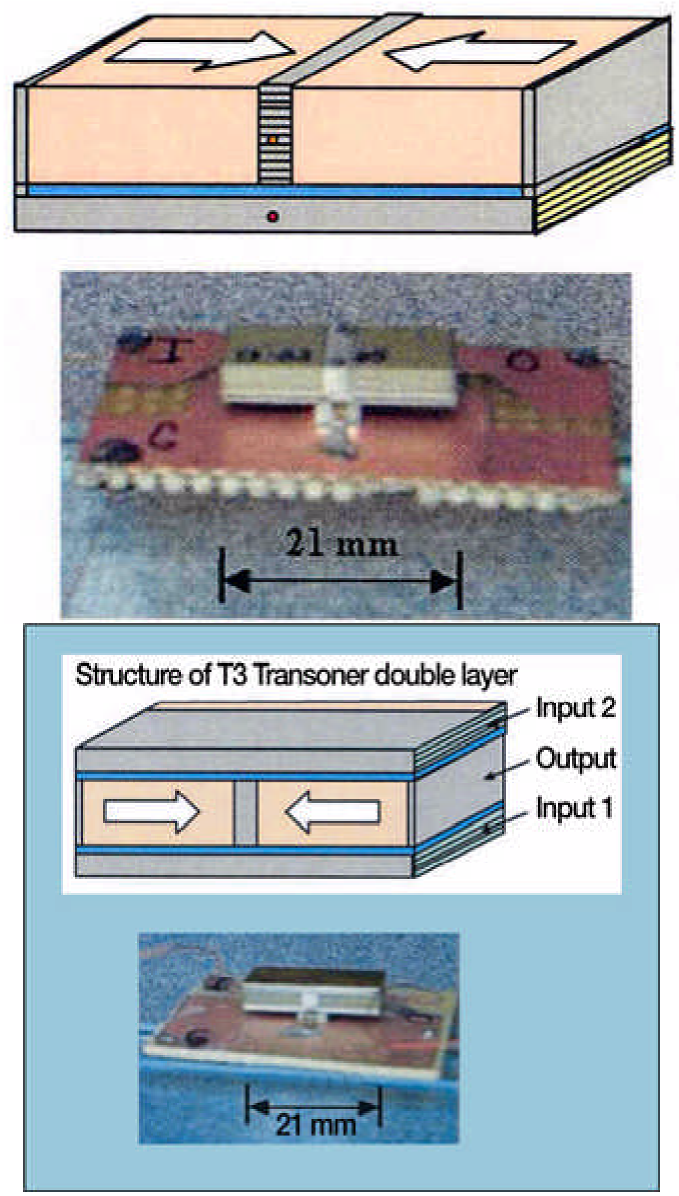
Novel High-Voltage, High-Power Piezoelectric Transformer Developed and Demonstrated for Space Communications Applications



A dc-dc converter showing a prototype high-voltage, high-power piezoelectric transformer used to demonstrate the feasibility of a modular approach.

Improvements in individual piezoelectric transformer (PT) performance and the combination of these PTs in a unique modular topology under a Phase I contract with the NASA Glenn Research Center have enabled for the first time the simultaneous achievement of both high voltage and high power at much higher levels than previously obtained with any PT. Feasibility was demonstrated by a prototype transformer (called a Tap-Soner), which is shown in the preceding photograph as part of a direct-current to direct-current (dc-dc) converter having two outputs rated at 1.5 kV/5 W and 4.5 kV/20 W. The power density of 3.5 W/cm^3 is significantly lower than for magnetic transformers with the same voltage and power output. This development, which is being done under a Small Business Innovation Research (SBIR) contract by Face Electronics, LC (Norfolk, VA), is based on improvements in the materials and design of Face's basic patented Transoner-T3 PT, shown in the left in the following figure. The T3 PT is most simply described as a resonant multilayer transducer where electrical energy at the input section is efficiently mechanically coupled to the output section, which then vibrates in a

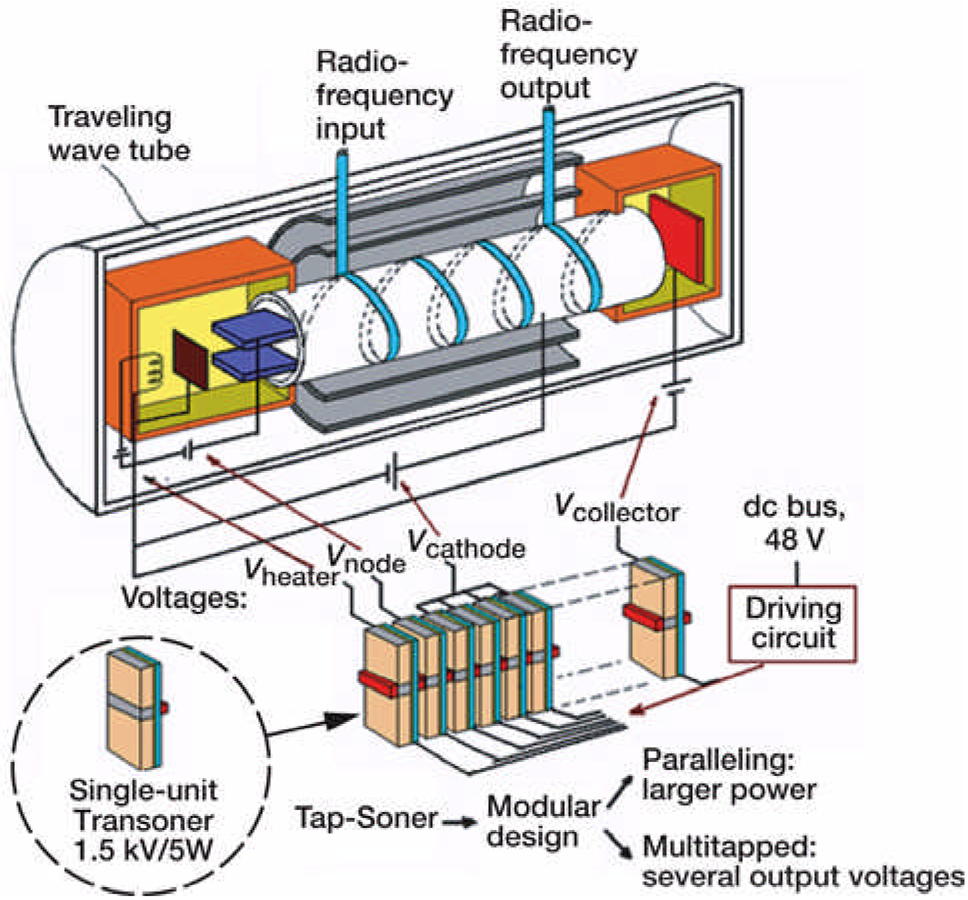
fundamental longitudinal mode to generate a high gain in voltage. The piezoelectric material used is a modified lead-zirconium-titanate-based ceramic. One of the significant improvements in PT design was the incorporation of a symmetrical double input layer, shown on the right in the following figure, which eliminated the lossy bending vibration modes characteristic of a single input layer. The performance of the improved PT was optimized to 1.5 kV/5 W. The next step was devising a way to combine the individual PTs in a modular circuit topology needed to achieve the desired high voltage and power output. Since the optimum performance of the individual PT occurs at resonance, the most efficient operation of the modular transformer was achieved by using a separate drive circuit for each PT. The output section consists of a separate output rectifier for each PT connected in series.



Left: Basic Transoner piezoelectric transformer used as starting point for developing a modular high-voltage, high-power piezoelectric transformer. Right: Improved double-

layer, symmetric Transoner piezoelectric transformer

Piezoelectric transformers are being developed as a potential replacement for the high-voltage, high-power magnetic transformers now used in power modules such as electronic power conditioners, as shown in the final figure, for traveling wave tubes used in space communications. Among the advantages offered by the piezoelectric transformer are significant reductions in mass and volume, no electromagnetic noise, and inherent high-voltage isolation. The performance goals of the current ongoing development are a 6-kV, 100-W four-output transformer, with an efficiency greater than 95 percent, suitable for operation in current state-of-the-art electronic power conditioners.



Operation of a traveling wave tube using a high-voltage, high-power piezoelectric transformer to replace the magnetic transformer in an electronic power conditioner. (Long description. Tap-Soner with modular design (paralleling--larger power; multitapped--several output voltages). Diagram shows traveling wave tube; radiofrequency input; radiofrequency output; and 1.5-kV/5W, single-unit transoner showing heater, node, cathode, and collector voltages as well as driving circuit.)

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